

**JOURNAL OF THE**  
**BOSTON SOCIETY**  
**OF**  
**CIVIL ENGINEERS**

**SEPTEMBER, 1928**

**Featuring**

**Ice Engineering**

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**Inspection of Structural Steel**



**Vol. XV**

**No. 7**

# BOSTON SOCIETY OF CIVIL ENGINEERS

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# JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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# JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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Volume XV

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## ICE ENGINEERING

BY HOWARD T. BARNES \*

(Presented before the Boston Society of Civil Engineers, May 9, 1928)

My subject to-night is one I have made an intensive study of for many years. It seems to be the habit of late to tack "engineering" on to all sorts of things. So I have coined the term Ice Engineering, because I have found in my practice of ice consultant that it is possible to lay out work and plan operations in ice situations to have these react in the manner forecast, and that in doing this it was possible to pay particular attention to the safety of houses, people, structures, and bridge piers, etc., and it seemed to me if that were possible I would be excused in attaching the honorable name of "engineering" to the subject of ice.

When we think for a moment of the tremendous cost of ice and snow we might call it a tax to Jack Frost; each year, then, it seems to me the subject demands more careful study. We realize in the operation of railways and in the removal of snow in the cities what a great price we pay. In New York alone each snowstorm costs a million dollars for just the removal, without counting the losses to transportation and the inconvenience to people; and when we consider that there are perhaps five or six of these snowstorms in the winter, the sum is considerable. The freezing of the St. Lawrence River and the closing of the Port of Montreal every year for five months means a loss of something like \$15,000,000 a week. The problem of the extension of navigation alone in Montreal is an important one economically. It costs a great deal to operate taxi cabs, railways, etc., under storm conditions. Nearly every flood which occurs due to ice might be prevented. Such floods cost the community millions of dollars.

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\* Professor at McGill University, Montreal, Canada.

If we can wrest from the ice-bound conditions a small percentage of what we lose each year, then it is worth while, and I feel that after these many years of physical research and study of these methods, which I wish to describe to you tonight, for ice destruction, the amount of property and amount of money already saved would quite compensate me, if nothing else were done, for the trouble taken and the work that has been performed.

I hope this evening to give you a picture, as nearly as possible, of the development of this work.

### NATURE OF WATER

First of all let me recall to you the nature of water itself. Water, to the chemist, has long been known as not by any means a simple liquid. Water is what they call an associated liquid. The chemical formula for water is  $H_2O$ , but the chemist has long told us that it is only in the vapor that we get the simple  $H_2O$  molecules. When this vapor condenses to a liquid these molecules associate to double molecules, for which the name *dihydrol* has been given  $(H_2O)_2$ . It appears that so highly associated are these that the single or monohydrol can no longer exist in the liquid state. Now the chemist goes farther and tells us that there is a still more complicated association in water, and that this association appears to be in the nature of a triple molecule, and that this triple molecule appears as soon as the liquid water appears, and that there is a ratio between the triple and the double molecules. This triple molecule has been given the name *trihydrol*  $(H_2O)_3$ . As water becomes colder more of the dihydrol passes over into the trihydrol, until at the freezing point the dihydrol all turns into trihydrol. When the concentration reaches 37 per cent then the trihydrol can appear as solid particles visible to us as ice.

It was Sutherland, in 1910, who attacked this problem in the light of the work that had been done at that time on the physical properties of water, specific heat of water, density, compressibility of water and viscosity of water. He found by studying all of these properties that it was possible, through analysis, to deduce the percentage of trihydrol, or ice, which existed in water or could exist at any temperature, and that from the freezing point, which is the point of saturation of the trihydrol, up to the boiling point, there was a constantly decreasing amount; but at the boiling point there was still 17 per cent of trihydrol, or, in reality, there was 17 per cent of the matter which we know forms solid ice.

So we must realize that water contains ice at all temperatures. When we boil water for tea we are boiling ice water. We cannot see the



ice, however, even microscopically, until the freezing point is reached, when the ice becomes a colloidal suspension in the water. Then the particles become sufficiently large and numerous to form the first slight visible suspension, and this first formation is a coagulation or clot of ice particles in the water. When we realize that water is already almost 40 per cent ice before it freezes, we can see how the first run of ice, when the temperature drops below 32 degrees, may be very great, because the energy has been taken out before 32 degrees is reached, and 40 per cent is all ready to separate out as ice without any further exchange of energy. There are many cases where it is difficult to freeze water. In capillary tubes, for instance, you ask. That is quite true, because we can supersaturate water with trihydrol when there is nothing to start the coagulation in just the same way that we can supersaturate a salt solution readily; but under natural conditions, in a running stream or in a lake, we do not get that condition fulfilled, because the stream is open to the air to absorb large quantities of atmosphere, and it also contains fine particles, such as weeds, dust or sand in suspension, which form a starting point for the production or coagulation of the solid ice.

The first run of ice in the autumn is always the greatest, and recently I have been able to show that what I call the ice-forming power decreases, just as though the water exhausts itself after producing the first quantity of ice.

I have found that water may exist in an active or passive state with respect to ice formation. When the first cold weather comes in the autumn we always get the greatest trouble, because there is the largest formation of ice. During a prolonged cold spell less and less ice is produced, and long cold weather results in less ice trouble than a series of cold and mild spells.

Our knowledge of the presence of ice dissolved in water is one of the most helpful things we have as a basis on which to work. We try to avoid the coagulation of these ice particles in the running stream by various means, and I have been studying various methods for destroying the liquid ice particles and reducing active water to the passive condition. One of the fundamental aims is to attack the ice before it forms to give trouble.

Another very important principle upon which this subject is based is the fact that it requires such a minute change in temperature to start the coagulation of these ice particles. As long as the water remains at 32 degrees the ice flows in colloidal solution; but if the temperature falls one-thousandth of a degree or less below freezing it begins to form

solid ice. On the other hand, under the influence of an exceedingly small temperature elevation — one-thousandth of a degree above freezing — the formation of solid ice will usually be prevented, and the loosening of the ice crystals will occur. So, if the rack or metal of a machine is kept one-thousandth of a degree above freezing, ice cannot form on it. There are several methods of doing this. One used quite successfully is the application of steam or electricity for heating the racks.

Then there is the use of heat in the form of a radiation. It is necessary to get energy into the water to prevent and destroy the formation of trihydrol, not just at one spot but over a large area. If steam is used as a source of heat only the water right around it can be heated; the heat cannot be radiated over any distance. All the heat applied from the steam is carried off by the water in convection streams. Nature has taught us a better way of applying heat. We know that most serious shutdowns of power houses are relieved in a very few minutes as soon as the sun rises, because the rays of the sun, even if they do not strike the water directly, cause a very small interchange of energy between the water and the ray. There is an absorption of the ray as it passes through water. One millimeter of water will absorb the long heat rays out of the sun. The short heat rays and the red rays will be absorbed in the first 3 feet. The penetration of the yellow and green is much greater, and will go 40 feet or more and affect ice 30 feet down. It is the energy in this light which destroys the ice formation.

This has indicated a way for controlling ice situations, and as far as possible to distribute heat over a wide area we must apply the heat energy in the form of radiation. It is the light rays, rather than the heat, which destroy the ice. Therefore a very small radiation of energy will do a very much greater amount of good than a very much larger quantity of energy in the form of steam.

#### COLLOIDAL ICE

I have made a careful microscopic study of the ice which first forms in water at the beginning of freezing, and the slides have revealed the fact that these particles are without crystal form. If allowed to remain undisturbed they gradually grow into the feathery form characteristic of a snowflake.

The study has shown that water is a colloidal solution of ice and that this solution is ready to coagulate into the solid form with the slightest fall of temperature below the freezing point. Rapid agitation, such as occurs in waterfalls or rapids, considerably facilitates the formation of



this ice, which accounts for the abundant production of ice in a turbulent stream.

The little particles of ice are nothing but small round discs, resembling the scales of a fish, and usually never attain much size as they are moved rapidly in a flowing stream.

This first run of ice, which is very abundant in the early autumn, is known as "frazil" and gives the most trouble to power-house operators.

There is another form of ice which is called anchor ice, and this grows on the surface of submerged rocks or other objects, and always forms under open water conditions and seldom under a surface of ice.

When water at the freezing point flows across a submerged surface, the trihydrol molecules will be precipitated on this surface very readily, even before the water is supercooled.

The trihydrol molecules possess the density of ordinary ice and are therefore lighter than the dihydrol or water molecules. They will therefore be drawn to the surface, where their concentration will be increased above that normally existing at the freezing point. The result of this increased concentration is a deposit of ice over the surface, — this deposit being the more rapid the swifter the water flows. Hence, we may have this ice forming on the rocks or stones or the wheels of a turbine before it appears anywhere else.



FIG. 1. — ANCHOR ICE DEPOSITED ON A COPPER WIRE IN THE EXPERIMENTAL TANK. WATER TEMPERATURE 32° F.

In Fig. 1 I show some of this anchor ice which has been deposited on a wire immersed in my experimental tank.

Owing to this hydrodynamical principle of the flowing water, the shape and character of the surface influence the rate at which the ice can be deposited on it.

#### ICE-FORMING POWER OF WATER

Some experiments were made recently to determine the rate at which ice can be formed in water.

An experimental tank was constructed containing water cooled in a room kept below the freezing point. To facilitate the cooling effect

an electrical fan was made to blow across the surface of the water. The water was stirred rapidly, and immediately the freezing point was reached the time was taken during which ice formation occurred. This ice was in the form of frazil and anchor ice, the water being stirred too rapidly for a sheet of surface ice to grow. At the end of half an hour the ice was removed from the water with a scoop and its amount measured. At the end of the next hour the same process was repeated. It was found that during the next hour the same amount of ice was produced as had been made during the first half hour. In the subsequent second hour only one-third of this amount of ice was made, after which, after four and a half hours, practically no more ice was produced. In order to re-establish the active condition of the water, it was necessary to allow the water to remain inactive for at least twenty-four hours, or use fresh cooled water.

### ICE CONDITIONS IN NATURE

In nature we have existing colloidal ice, snow ice, frazil, and anchor ice carried in the open water.

The most active agent for the production of ice is the earth's radiation. A cold atmosphere flowing across the surface of the water will, if dry, produce a certain quantity of ice, but it is insignificant compared to the amount produced by the earth's terrestrial radiation.

The most active agent in ice prevention is the action of light, and we observe that as soon as the sun rises in the morning the ice production almost completely stops, and that which has been formed during the night along the bottom of the river rises to the surface and floats on the surface.

Some very interesting observations have been made on the influence of light in ice formation. Along the River Neva, in Russia, the fishermen along the shore, when they lose their anchors, merely wait for the ice production in winter time, when they know that the rising sun will bring the anchors up encrusted in ice.

### ICE-FORMING POWER OF THE WINTER MONTHS

The following diagram (Fig. 2) will illustrate the ice-forming power during the winter time.

During December, when the sun's rays are weak, the ice grows with great rapidity, and continues about the same during January,\* but in February, with the increasing power of the returning sun, the ice growth reaches its limit, and very little new ice is made after the middle

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\* This has no reference to what I call the ice-forming power of water already discussed.



of February. By the middle of March it has begun to decrease, and although cold weather may produce a temporary growth of ice, the rays of the sun are sufficiently strong to offset it. In April the ice disappears very rapidly.

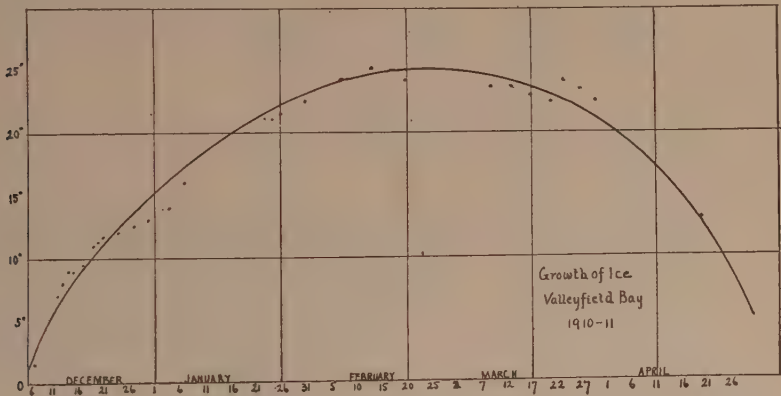


FIG. 2. — CURVE TO SHOW RATE OF GROWTH OF ICE DURING VARIOUS MONTHS OF THE YEAR

The following diagram (Fig. 3) illustrates the conditions between ice formation and no ice formation in a stream.

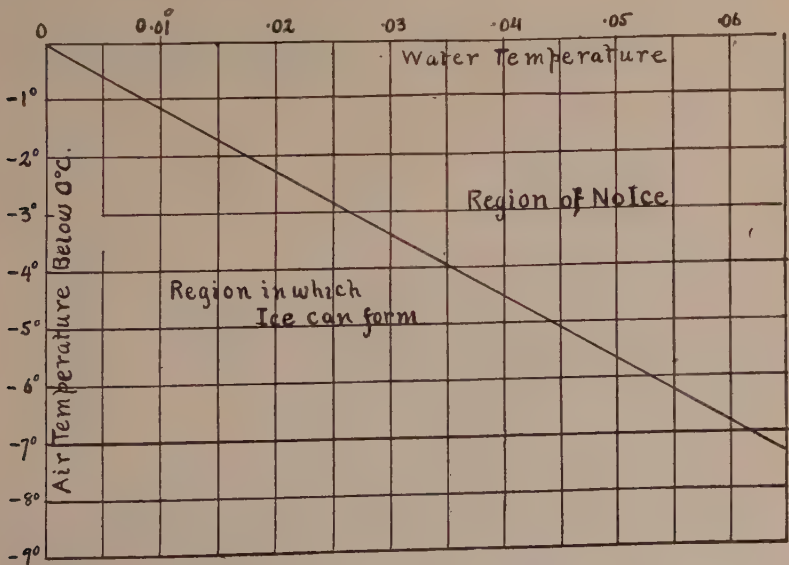


FIG. 3. — CURVE TO ILLUSTRATE BOUNDARY BETWEEN ICE AND NO ICE

Nowhere do we find a more delicate poising of the forces of nature than in the equilibrium of ice and water. Even in the coldest weather there is a limiting temperature of water at which no ice can form. We find that the boundary curve gives a very exact limit for any given air temperature. For instance, in Boston, when we know the mean winter temperature we may calculate from this curve, knowing the average temperature of the water, the exact thickness the ice will attain.

### SUN ON THE OPEN WATER

Light has the greatest action on the temperature of the open water, and in this respect a covering of surface ice prevents the storing of the sun's rays in the water. When the surface ice is removed the sun warms the water and the temperature begins to rise.

There is an advantage in removing the ice from the water, after the first of February, in order to get a complete storage of the sun's energy.

The light in the early morning has the greatest effect of any time in the day. At that time the air is calm and pure and the light rays are more effective.

In my experiments I have tried the effect of putting a lamp directly in the water, but I find the mechanical heat goes directly from the lamp to the water and causes a vortex stream in one direction, which is troublesome.

### ICE DEPOSITED ON SUBMERGED SURFACES

To show how readily some surfaces gather ice upon them the accompanying picture (Fig. 4) shows ice gathered from water on a ball of steel wool. So sensitive is this material that ice will commence to deposit on it when the water is two-hundredths of a degree above freezing. A point or sharp edge appears to attract the ice before a flat surface, as before mentioned.

Frazil forms readily on a piece of frayed rope, and this method of detecting the active state of the water in winter is in use and has proved more sensitive than the most delicate thermometer. It is the mechanical action of the water flowing past the edges or points which causes the precipitation of the ice particles.

### HIGH TEMPERATURE HEAT

The effect of intense heat radiation on solid ice is very interesting, and, in fact, the whole action of powerful radiation on ice induced me to try some heat-producing medium as an active agent in relieving ice



accumulations. Some such material is found in the burning of aluminum, as in the thermit, a form of which is used so much for rail welding. Every one has seen at one time or another the very great heat developed in this reaction. Thermit is a mixture of aluminum metal and iron oxide. When the mixture is raised at any point to a temperature of 2,800 degrees Fahr. the aluminum combines with the oxide and liberates the iron, together with the large heat of formation. This heat is contained by the iron and raises its temperature to a white heat of 5,000 degrees Fahr. This molten iron gives out intense heat radiation which penetrates through ice and water with great power. There is no ex-



FIG. 4. — ANCHOR ICE DEPOSITED ON A BALL OF STEEL WOOL IMMersed IN THE EXPERIMENTAL TANK. UPPER MASS IS OF SURFACE FORMATION. WATER TEMPERATURE 32.02° F.

plosion of itself, but the hot iron reacts with the water or ice generating hydrogen gas with such suddenness that a great explosion results, and the ice is torn asunder with great power. The explosion is more powerful than a steam boiler explosion in proportion to the extra amount of hydrogen produced. Not only is the steam produced, but the steam is decomposed into hydrogen gas which, coming out, burns with the oxygen of the air.

To practically apply this material in ice engineering work the thermit (a special ice thermit) is put in a metal container with lined and insulated walls and fired from the top with a fuse or electric squib with a flash powder. The whole container must be absolutely water tight, for wet thermit will not burn. The bottom of the container is a thin lining of metal through which the molten iron melts its way like hot water through sugar. When this glob of molten metal comes in contact with the ice or water the explosion results.

By applying this thermit heat container in water the result is similar to setting the sun in the water for a short time. The great inrush of energy causes a relaxing of the crystals of ice forming the accumulation, and the heaving action of the explosion cracks and disturbs the whole mass, allowing the water of the stream, which has been held back in flood, to gather way and melt its way through the pack. When once the water has been started the small stream soon washes away much of the ice, and soon wears away the accumulation at that point, and the river is rapidly restored to its bed.

The molten iron is shot out in all directions through the ice mass like bullets from a gatling gun, and in this way helps to convey the heat over a large area.

The following picture shows the explosion of a solid block of ice with a small amount of thermit reacted in a cavity cut in the block. The force disrupts the ice and completely destroys it in a few seconds.

When a small amount of thermit is reacted in ice the heat intensity is not sufficient to explode the ice, but instead the block glows with a brilliant phosphorescence. The phosphorescence always precedes the explosion.

The slow-motion picture of a block of ice reacting up to and past the explosion point illustrates very well the action of the intense heat radiation on the ice structure. (This picture was shown in the lecture.) Vapor can be seen coming out of the sides of the cake of ice just before it explodes just as though the ice was becoming white hot.

The action of thermit in ice is very interesting. The transference of heat from a body at 5,000 degrees to a body at 32 degrees is not easy to picture. What is the mechanism of transfer of heat from a very high temperature to one of low temperature across a boundary of molecular dimensions? The temperature drop must be very large, and I have found the power of the explosion depends on this — the greater the drop the more violent is the explosion.

#### ICE JAMS TREATED WITH THERMIT

The great use of the thermit reaction is in relieving an ice jam. These jams start on the St. Lawrence River usually by the swinging out of a great field of bordage ice. The Indians used to do this in the winter time in order to gain a crossing or ice bridge to the opposite shore. Now it is forbidden, because some of the worst ice jams with floods have occurred on the river from this cause. The floating ice coming down in the current packs into this field ice and builds back against it, causing the surface covering to extend many miles against the current. With the

infiltration of frazil and anchor ice as well as snow the surface ice begins to build down to great depths. The channels are blocked and the floods ensue, until a sufficient head is raised to shove the ice down stream into the pack. A cross section of the river through the ice packs will show the slush ice adhering to the underside of the surface sheet. The surface is buoyed up by the floating power of the slush underneath and great hummocks are produced. We can readily locate the position of hanging dams by these humps. An ice breaker can break up surface ice readily, but finds greater difficulty in the great masses of slush underneath.

Thermit is particularly effective in destroying this slush accumulation. And the thermit reaction will serve to open great holes and cavities



FIG. 5. — PREPARING THE FIRST THERMIT HEAT UNIT, FEBRUARY 24, 1925, AT WADDINGTON, N. Y., ON THE ST. LAWRENCE RIVER

in such masses, into which the water will filter and wash the remaining ice away.

There are two types of ice jams. One comes from the fact that the river is carrying more ice than the channel will permit when it becomes choked. The other kind of jam comes from the accumulation of frazil under the surface and the gradual building down, accompanied by shoves, until the whole becomes securely cemented in place. Such a jam usually has a key pack where the relief will cause the ice to move on down stream. The jams on the St. Lawrence are of this type.

The first jam treated with thermit was at Waddington, N. Y., between the New York shore and the Clark Island shore. The flow of the river was perfectly free in the south channel of the St. Lawrence until some ice gave way above and came down and jammed like a cork in a



bottle. Immediately it jammed it became filled in with frazil and anchor ice. It was not very large, but was interesting to work on. It was the first to be treated with thermit. When we put our first charge in the slush hole through the ice it was a miracle I was not looking down into the hole. Fortunately I went back about 20 feet and waited to see what would happen. We had a wire running to the flash powder, about 50 feet long. I expected nothing but incandescent rays from the thermit. Instead I got a very big explosion. The ice and water came up and went all over us. The ice was destroyed for 15 feet all around. The next day



FIG. 6.—OUTBURST OF FIRE, PHOSPHORESCENT ICE AND INCANDESCENT HYDROGEN GAS FROM THE DISRUPTION OF A 400-POUND ICE BLOCK BY MEANS OF TWO POUNDS OF THERMIT

we found that an air hole had opened up much larger in size. It showed the effect of the heat. The next day we put two more containers in the slush ice of the jam.

The last container was let down 20 feet in the toe of the jam. When that was fired it evidently took out a good quantity of this ice which acted as the support of the jam. In twenty-four hours the whole ice jam came away. We did not get photographs of those explosions because we had not expected them.

The next jam I treated was below Ogdensburg. Two thermit containers were used and we loosened the whole jam, which started to move out in nine hours.

I was called to treat the Allegheny ice gorge in 1926. This was an ice jam that held the water back in flood and caused great inconvenience at Oil City and Franklin, Pa. The containers used at that time were



FIG. 7.—WADDINGTON, N. Y. HEAD OF THE PULPWOOD DOCK  
ICE JAM CUT BY THERMIT TREATMENT

not satisfactory, and I had to start in and devise a suitable one for applying the thermit. They all had to be made on the spot, and it was quite a piece of research to know how to attack that big gorge and what to use to put the thermit in. In order to relieve the flood I used thermit to burn out the ice through the pack and thus liberated the water above. Having got the flood down I held it there until I could take the ice out.

Of course if the ice had been allowed to come down on Franklin it would have been a very bad thing. So we attacked the ice at the lower



FIG. 8.—CHIMNEY ISLAND ICE JAM BELOW OGDENSBURG, N. Y. SECOND  
JAM TO BE TAKEN OUT WITH THERMIT. OBSERVERS SEEN MAKING  
SOUNDINGS TO LOCATE THE KEY POINT

end. This was treated quite thoroughly with thermit in order to get the water through. The lower ice raised a little and the upper end came down and gave a more normal drop in level. A great many places were opened up in the pack to let the sun in. While the upper end was rotting out the lower end remained hard and firm. Nature brings the upper end down on to the lower end, and it is only a mechanical push that will move the lower end. So we rotted the ice at the lower end to get it ready for the ice from the upper end.

During the last two days some ice stuck down below the Reno bridge about 4 miles, and the flood raised the ice and the bridge off its



FIG. 9.—ALLEGHENY ICE GORGE. EFFORTS TO SAVE THE BIG ROCK BRIDGE

piers about 18 inches. The bridge floated on the ice. We were afraid the ice might move and put the bridge out of alignment, so we treated the ice with thermit and coaxed the water to the other side of the river, so if the ice moved it would not carry the bridge away. We used about five or eight thermit containers and brought the bridge back inch by inch on to its piers. We dropped the ice down about 2 feet and then sent a gang down the river to get the ice down. We worked simultaneously on the last day, here and below, so that the whole thing moved out simultaneously, and inside of three hours we did not have any jam. The bridge went back safely on its piers.

An ice jam like this will kill more fish than anything. There is no damage to structures from using thermit or to power houses and no fish are injured by it.



At Belleville, Ontario, I had a more satisfactory piece of work, because here I prevented an ice jam. I so treated this beforehand that the ice passed out without flooding at all. Wherever conditions look as if you might get a jam it is wise to rot the ice out, so that when the ice comes down the stream it will merely push on through. I went there last year when conditions looked pretty bad and started to treat the ice to keep the flood level down and rot it out so that the ice above would meet no resistance when it came from the lake. The river out into the



FIG. 10. — CALCIUM CHLORIDE TRENCH  
AT BELLEVILLE, ONTARIO. ICE 20  
INCHES THICK

Bay of Quinte in Lake Ontario was filled up solid with anchor ice and frazil. Water was running around the edges of the jam here, and running around to the side of the island. It was practically solid. I started to treat this by selecting the deepest part of the main channel. That was in February. I put in three units of 150 pounds each of thermit. The ice was soon destroyed, the water clear, and in twenty-four hours it was largely carried through, which shows the action of water in helping to clear up these channels. The levels dropped above and rose below as the cracks opened up. On account of preventing the jam at Belle-

ville the fishing was better there than ever before. By keeping the ice from packing with thermit the spawn were not destroyed.

Calcium chloride is also very effective in destroying ice. We trenched the ice at Belleville in 50 foot squares above the bridge, and when the field broke the pieces passed down below the bridge in small pieces.

Some one asked what is the magnitude of the pressure allowable on a concrete structure or a dam from ice. There is a great deal of controversy on this point. The best thing to do is to keep the ice along the structure rotted out, because one cannot tell what the pressure is going to be. It is very variable. A great saving will be made in the construction of dams if a minimum allowance is made for pressure and definite instructions given to destroy the ice. A very simple way is to lay a line



FIG. 11. — PREPARING TO SPREAD CALCIUM CHLORIDE WITH ORDINARY ROAD SPREADER TO FORM A CHANNEL THROUGH SURFACE ICE

of calcium chloride along the line of the wall, which will give a series of holes through the ice, and after the middle of February these holes never freeze to the same strength as the rest of the ice. Another good thing is to mix 25 per cent of gravel or sand or coal dust with the calcium chloride, so that it will be carried into the ice, and the ice will never attain its full strength.

Those who have been using flake calcium chloride find the ice pressure merely crushes the rotted ice along this line and does no damage. It is preferable to use the lump calcium chloride on the ice, spread from 6 to 8 pounds to the square yard. You will find that these lumps will drill holes and convert the ice into a honeycomb structure. It is very simple and may save a great deal of trouble.

At Richmond, Quebec, I treated the ice by checker-boarding it with calcium chloride. This spring they thought they would take a chance, and

took a gamble on getting through. They had the worst flood in their history, which cost them \$200,000 inside of two or three hours. The expenditure of \$500 to \$800 on chloride would have prevented it. Every community has to learn its lesson, but it was very sad in this case because many people lost everything they had. It seems strange we cannot get the gambling instinct out of our minds when we are dealing with lives and property. But I think the time will come when the provincial or state governments will have to have an ice patrol to go out and destroy the jams, because the farmers suffer and the villages also. Take Vermont, for instance. Of course the recent floods were due to rain, but a great many floods that occur in this country occur because of ice. The government has got to face this problem. Ice breakers are the best thing for ice destruction on a large scale where they can reach the ice, but one of our main problems is to relieve congestion in power channels. These are usually designed to be refrigerating machines instead of ice-preventing machines. One of the best designed is at the Queenstown development of the Hydro-Electric Power Commission at Niagara Falls. It is designed at the intake to prevent the velocity at any one point from sucking ice down. Large floating pieces which will obstruct the ports may be prevented in this way.

The canal proper was especially well designed with respect to ice conditions, because it is narrow and deep. The narrower and deeper the canal is the better it is. A submerged pipe is better than anything else. A great many penstocks have been made shallow and wide in order to give a large flow and save expense, but it is not realized how much greater ice formation that means. One should try to get as much of the water to flow under the surface. Design for that and you will be free from ice troubles.

### ICEBERG CONTROL

I got the idea of trying to break up icebergs by heat from watching the effect of the early morning sun on them. If we can get some intense heat into an iceberg suddenly we can crack it, just as we can crack glass by applying a hot point at one place. If we go out to sea 60 miles or so and find great waves running, it is hard to get on the icebergs, but my first experiments were made in the Harbor of Twillingate to test the effect of heat. After proving the physical fact, my problem now is to apply this heat from a ship at sea without danger.

In our first experiments we crawled right up on the berg with scaling ladders. We wore life belts, of course. We realized, however, that it would be necessary to have some means of applying heat without getting



on to the bergs as that is too dangerous, but I had first of all to prove that heat could be used.

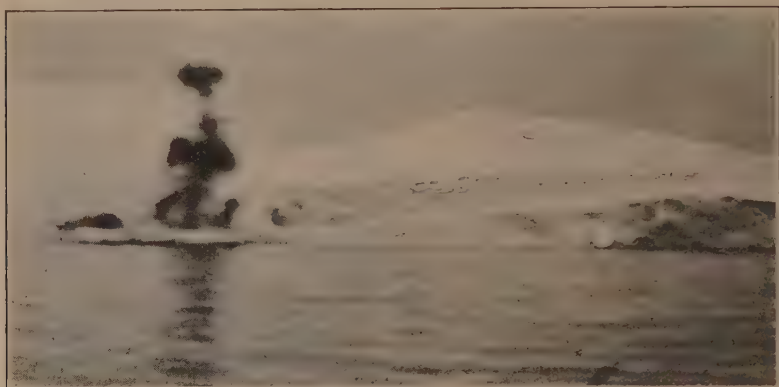


FIG. 12. — EXPLOSION OF ICE ON THE FIRST ICEBERG TO RECEIVE THE THERMIT TREATMENT, JULY 26, 1926

Ordinarily an iceberg is about two-thirds under water. Ten per cent of the iceberg is air. Air was pressed into the berg with the snow on Greenland. I have collected air from an iceberg and analyzed it and

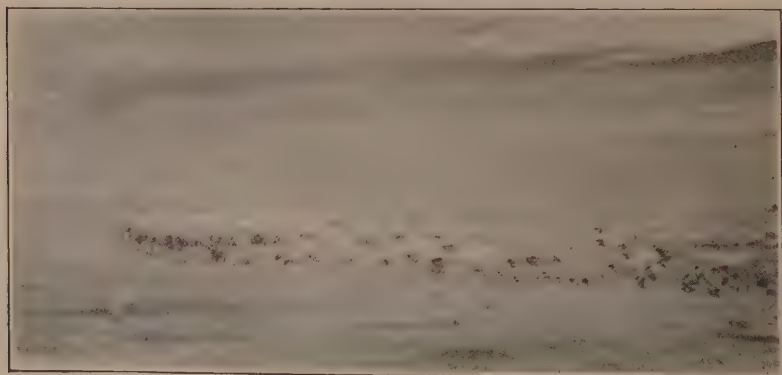


FIG. 13. — FRAGMENTS OF DISINTEGRATED ICEBERG, FROM THERMIT TREATMENT

found it to be the same as the air we are breathing today, although it must be thousands of years old. Our first iceberg had remained intact and perfectly stable for about three days before we treated it. There was a long protruding plateau which looked nice and firm, so we

scaled it and planted some thermit there. The picture (Fig. 14) shows how we mounted with our scaling ladder, and shows my friend with his life belt ready to come down to the dory. We planted 100 pounds of



FIG. 14. — SETTING THE FUSE FOR A THERMIT CHARGE  
PLANTED IN THIS SMALL ICEBERG

thermit about 3 feet in the ice. We had not the tools with us for planting it deeper. Thermit should be planted 20 feet or more. It is very beautiful inside an iceberg. There are little lakes and little islands of white ice in the center. It looks like fairyland. Quite a wonderful experience!

The explosion of the first charge of thermit is shown in Fig. 15, and in Fig. 13, the plateau disintegrated by the force of the explosion.



FIG. 15. — ICEBERG BEING DESTROYED

In two days that berg was practically only one-third of its original size. During the night the whole inside came out. Immediately after the explosion and all that evening one could hear cracks, and there was a

great noise in the night when the inside came out. This shows the berg two days afterward.

In another berg, we used two charges, one of 60 and one of 100 pounds. We found the smaller charges more effective, because most of the larger charge was wasted in the air, because it could not be sunk deep enough. There was only one piece of the berg we could find next morning. We did not see anything happen to it that evening, but the next day it was



FIG. 16. — CLOSE-UP OF A FRAGMENT FROM AN ICEBERG  
BROKEN UP WITH THERMIT. OBSERVE THE THERMIT  
HOLE ON THE WATER LINE AND THERMIT SLAG ON  
THE SIDE

gone. We found this piece and the hole that the thermit blew out of. There was thermit slag on the outside.

If there are any questions I would be very glad indeed to answer them.

### Discussion

QUESTION: I should like to ask what method you use for making the holes?

PROFESSOR BARNES: Brute force. We simply cut them out. That was all we needed for our experiments because we were only trying to determine whether heat really had any effect. The United States Coast Guard International Ice Patrol were very much interested in what we were doing, and they objected to our use of thermit because they said "you have to get on the iceberg and put it in and fire it." When the waves are high you can't get near these bergs, and they are difficult to climb at best. It is impossible to mount an iceberg in the ocean; and you do have to go on to it. You can't shoot a shell into a



berg. I thought possibly I could make thermit into a shell and fire it on to the berg and set it off. Heat is the only thing that cracks the bergs. I have something now which will make its own hole as deep as we wish to have it, and when it is in place will fire itself without any wires. With thermit we had to have a wire running on to it to set the fuse off, and we found that the iceberg cut the wire, so we had to make a fuse without wires and make it long enough so that we could get off the berg. First we put in 10 feet of fuse, but we did it in order to be on the safe side. Now I am hoping to be able to apply this new method of getting heat into the iceberg. I shall do it some time soon. If not this summer then next summer. It is very slow experimentation, because we haven't icebergs in our backyards to play with. These icebergs are pressure ice, made by the compression of snow flakes. They are exceedingly hard and there is no line of definite cleavage.

QUESTION: I remember seeing them drive a lame horse back and forth across the ice with a big rope tied to the two rear wheels.

PROFESSOR BARNES: Yes; they could put a vibrator on the ice, also, to coax the trihydrol out of the water. You can do it in a great many ways.

QUESTION: I have been under the impression that frazil forms when water is in contact with cold air. I wonder whether the difference between frazil and anchor ice is only one of temperature.

PROFESSOR BARNES: It is due to the agent that ice forms upon. Frazil forms under water. It forms on the top more copiously. You will get it all through the water. You will get surface frazil also — scum ice. At night not only the surface but the whole volume of the water gets cold. Anything that brings the water down faster than the heat is kept up by the ice forming in it will cause more ice to form. The lower the temperature the easier anchor will deposit on the bed of a stream. Radiation is not only the cause of anchor-ice formation. It is a contributory cause and probably the most effective one.

QUESTION: You mentioned using charges of about 100 pounds. Did you make tests to see whether larger or lesser charges would be more effective?

PROFESSOR BARNES: We found that a large number of smaller charges were better than one big charge if near the surface, but if placed down deeper, then one single charge will do more effective work than a lot of little ones.

QUESTION: What is the approximate cost of thermit per pound?

PROFESSOR BARNES: The Metal and Thermit Corporation sells it at 40 cents a pound. One hundred pounds would be \$40. You don't

want to waste any of it. But it is more effective than the equivalent amount of dynamite.

QUESTION: How long was required to clear up the jam on the Allegheny River you spoke of?

PROFESSOR BARNES: I worked there ten days. The weather was against me the first week. All the work the first week was done underneath. People got the impression nothing was being done. All of my men knew what was being done. The official report of my work is now in the War Office in Washington. He came out there and was present when the ice was taken out. He was familiar with what I had been doing and saw the result of the work and put in a splendid report at Washington. That is the only official report that was made.

QUESTION: Is it possible to adjust the size of charge to sufficiently heat a reservoir so as to prevent frazil ice?

PROFESSOR BARNES: It is impossible, because you cannot restrain the action. A large part of the heat is lost. There are two things you can do. You can act on the ice by heating the water with steam or hot water or electricity. The most effective way, however, is to apply heat in the form of radiation. That has much more effect in a penstock or entrance to a wheel pit or water works pump. It is done by lights shining down on the water. Drop a ball of steel wool in the stream or river and examine it during the evening, and when that picks ice out of the water it gives warning that it is time to get to work and be prepared for trouble. Because it will pick ice out of the water before it quite gets down to the freezing point. A piece of frayed rope will do it also. When ice begins to form on the frayed rope then you have an advance signal of trouble from ice and you must get the steam up. All you can do is to start the steam auxiliary plant probably. A system of flood lighting would help to counteract all that.

QUESTION: To what depths will the lights penetrate?

PROFESSOR BARNES: That depends on the strength of the light. This is the first time these experiments have ever been described.

QUESTION: At what depth would thermit be effective?

PROFESSOR BARNES: In my experiments we put it down 3 feet. There is no reason why it should not be effective at any depth.

QUESTION: Could you drill holes in the ice with a steam jet?

PROFESSOR BARNES: I never used steam jets.

QUESTION: How did you get deep holes in that jam?

PROFESSOR BARNES: We cut down through the surface ice with axes.

QUESTION: How is the action of flood lights as compared to compressed air?

PROFESSOR BARNES: The bubbling method is very effective. It tends to keep the heat up. I don't know, however, how the two methods would compare. In some cases they use electric heating. That is not an economical way, however. I never myself installed any bubbling system. I know it is quite effective. If you can generate hydrogen gas by reaction in water it is much more effective.

QUESTION: You spoke of starting vortices in penstocks by using submerged lights. How does the effect show up?

PROFESSOR BARNES: There is a change — a drop — in the efficiency of the turbine. It begins to pound. The big noise it makes is quite terrifying when you hear one of those runners going around with a vortex running through.

QUESTION: I would be very much interested to know the actual drop in efficiency resulting from vortex?

PROFESSOR BARNES: I have no figures on that, but it is very easily determined. The vortex is quite easy to produce.

MR. DORR: I see by the newspaper account of the flight of the Bremen that paraffin was applied to prevent ice forming on the wings. Has any attempt been made to prevent the formation of frazil ice on turbines or wheels by the application of paraffin?

PROFESSOR BARNES: I don't think paraffin would last very well on the racks. I think it would be quite effective while it lasted. Perhaps a good graphite paint might do it. Ice will not adhere to a graphite surface. Paraffin would probably be quite effective. But I don't know whether even graphite would last long.

QUESTION: Is that commercial graphite paint?

PROFESSOR BARNES: I am thinking of graphite carbon-electrodes. It is quite possible that a graphite paint will be evolved effective on aeroplane wings.



## THE INSPECTION OF STRUCTURAL STEEL

BY DONALD L. MACDONALD,\* MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS

THERE is probably less known about inspection than any other phase of the structural steel industry. This is partly due to the fact that engineers are too busy to spend the time at the mills and shops necessary to obtain a comprehensive idea of what constitutes inspection, and also to the fact that the few who have been in positions to know the most about it have seldom taken the trouble to inform the designing engineers, who should know all about it.

The purpose of this article is to tell about inspection, so that a clear idea may be formed in regard to its use, value, and, in most cases, its necessity. This last statement appears strong, perhaps, but it should be remembered that the engineers who are most familiar with the manufacture and fabrication of structural steel are the ones who insist on inspection.

This article will be confined to one branch of the industry only — structural steel for buildings — but it is apparent that the rolling, fabrication, and erection of bridge steel is almost identical with that of building steel, so that most of the statements made will apply also to bridge steel. The word engineer will therefore mean architect, too, for the matter of inspection of building steel is sometimes left to the architect to settle.

A discussion of inspection may properly start with a few words concerning specifications, for they are the basis of inspection, and improperly written specifications are the cause of much trouble. Almost all rolled structural shapes and plates for buildings produced by steel mills in recent years have been made in accordance with the specification of the American Society for Testing Materials, entitled "Standard Specifications for Structural Steel for Buildings," issued under the fixed designation A9, adopted in 1901 and last revised in 1924. This specification has been in such general use that it now may be considered standard, and has been adopted by the American Institute of Steel Construction. It applies, of course, only to the quality of the steel as made at the mills, and does not apply to the fabrication or erection.

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\* New England representative, Pittsburgh Testing Laboratory.

Until recently no specifications which could be considered standard have been in force covering the fabrication and erection of structural steel, and as every buyer has been using his own specification the result has been confusion for the buyer, the fabricator, and the inspector. Recently, however, the American Institute of Steel Construction submitted a specification to the users of structural steel covering design, fabrication, and erection, and supplemented it later with a "Code of Standard Practice" covering conditions not touched in the specification. These are rapidly being adopted by the industry as standard, and the allowable stresses recommended are being written into building codes.

The inspection of structural steel naturally falls into three classes, as follows: mill inspection, which covers the rolled material up to the time it is shipped to the fabricator; shop inspection, which covers it from the time it is received from the mill until it is shipped all fabricated to the job; and field or erection inspection, which covers it from the time it is received at the job until it is erected in place. These three inspections, although separate in themselves, all together give complete protection.

Mill inspection consists of an examination of the rolled material on the hot beds for surface defects, and a check of the dimensions to insure their being in accordance with the standards. The inspector witnesses the tensile and bend tests, which must be acceptable to him, and reports them, together with the ladle analysis as obtained from the manufacturer. This, of course, must also be acceptable. If the buyer desires further protection in the form of a check chemical analysis, as covered by the A. S. T. M. specifications, the inspector obtains the sample or drillings from parts of the material selected by him, and forwards them to his own laboratory for analysis. The report which the mill inspector makes also includes a description of the pieces inspected, lengths, number of each, size, and heat numbers. Sometimes it is also possible to include the numbers of the cars in which the particular pieces are shipped. It should be noted that in the case of a small job the fabricator will often have enough material in his own stock to fill the order, and no mill shipments will be required. This is covered by the A. I. S. C. "Code of Standard Practice," which allows such stock material to be used if bought under an established specification, and of course there can then be no mill inspection. It is sometimes possible, however, to identify the heat numbers on the stock material, and by checking the records ascertain the quality of the steel as reported by the manufacturer.

Shop inspection consists of checking each member against the detail drawings, with particular attention to field connections. This is of great

importance, for if the shop is held to a high standard of workmanship the use of drift pins during erection will be reduced to a minimum, the steel will fit together properly, and the building will be completed earlier, which will result in the owner getting an earlier return on his investment. All pertinent conditions of the buyer's specification are checked to insure their being fulfilled. Finished members are checked for twists, bends, etc. All rivets are tapped and loose ones are cut out and redriven. The inspector keeps an eye on the various stages of laying out, punching, reaming, riveting, and machining, and shop assembly receives its needed attention, including checking the painting of inaccessible surfaces. No paint is permitted to be applied in the open during wet or freezing weather, nor unless the steel is properly cleaned. Reports are rendered periodically, listing all members, pieces, and shipments, and showing the progress of the work during the period.

Field inspectors see that the members are erected in their proper places and are not interchanged, that the columns are within the required tolerance for plumbness, and that connections meet without excessive use of drift pins. All field rivets are tapped and loose ones are cut out and redriven. If painting is included in the specification it is watched to see that it is carefully applied and all surfaces covered, and no paint is permitted to be applied in inclement weather. Reports are rendered periodically, listing the members received and erected, and showing the progress of the work for the period.

The above is an outline of what constitutes real inspection, and is the result of experience in giving engineers the protection which they desire.

Inspection is not new, but grew with the industry. When the Bessemer and open hearth furnaces were developed so that steel of the desired quality in commercial quantities could be economically produced, and the rolling mills were developed to keep pace with the steel, wrought iron was eliminated as a material for building construction. This was about 1890, and the use of structural steel soon became universal for certain types of construction.

When the first buildings with a steel frame were built there is no doubt that the engineers who designed them suffered all the worries incident to using a new material, and inspected it in all stages of its production. Not only that, but we are told that this inspection was usually made by the engineer himself, as it was considered too important to entrust to a subordinate. Soon methods of manufacture and fabrication were improved, standards were adopted, confidence was gained, and the engineer then relegated the inspection of the steel either to subordinates



or to people who made a business of inspection. There was seldom any question as to whether it should be made, however, for there was usually much to be desired both in quality of material and workmanship from the point of view of the engineer.

Today conditions are much improved. The ingots, from which the shapes and plates are rolled, are much better, but are still a danger point on account of gas pockets, pipes, and the short crop. Rolling methods have been improved. The quality of the steel is under close control, in fact it is so close that in an endeavor to save a few cents a ton the manufacturer often just attains the point of acceptance and sometimes falls a little below. Fabricating shop equipment is much improved, although shop methods and the different steps in fabrication have changed but little in the last thirty years, and this applies also to erection. In general, however, a great advance has been made, and structural steel enjoys an enviable position as a material for building construction.

In view of this it would be natural to assume that the necessity of inspection has greatly lessened. In fact, the need for inspection is as great as ever, due to that pernicious factor known as "Production" or "Tonnage." This, with one of its attendant evils, — the bonus system, — has resulted in the mechanicalization of the worker, a breakdown in his morale, the almost total disappearance of that pride of workmanship once so common, and an increase in the number of mistakes, due to the ever-present human element. This last result is particularly insidious, for it affects all branches of the industry, and is guarded against least of all by the industry. It may be said that a high standard of workmanship is maintained, but this standard only too often consists in just making it "good enough," and cannot be guarded against by simply writing into the specifications the phrases "The workmanship must be good" and "All workmanship shall be equal to the best practice in modern structural shops," or by specifying the tolerances allowed.

Countless instances can be given of failures and losses due to steel not being inspected in support of the statement that inspection is necessary, but these are known to everybody and are simply the results of poor work. The causes of poor work are much more important, and once these are clearly understood the value of inspection is realized. That engineers as a group are fully alive to the necessity of inspection is clearly shown by the fact that it is provided for in all standard specifications.

In view of the known benefits arising from inspection it seems pertinent to wonder why the maximum allowable unit stress used in

designing cannot safely be increased from 18,000 to 19,000 pounds per square inch if the steel is to be inspected, with resultant good workmanship, quality as specified, and errors corrected, for the saving in cost in that case would amount to at least three times the cost of inspection. This seems logical, for although 18,000 pounds per square inch is the maximum allowable unit stress at present, a large safety margin exists, for the steel usually can be safely stressed up to about 28,000 pounds per square inch, the elastic limit, with no resulting harm, and inspection corrects many of the conditions intended to be covered by this difference of 10,000 pounds per square inch.

We are all interested in the cost of inspection. This will vary with the tonnage, the rate of production, the design, and the distances between the mill, shop, and job and large centres of population, but for jobs totalling about 300 tons and larger it will be about \$1 per ton, or a little less, for mill, shop, and field inspection. As steel erected costs about \$100 per ton, the cost of complete inspection will therefore be about 1 per cent of the cost of the steel in place. If only two of the kinds of inspection are deemed necessary the cost, of course, will be proportionately less.

Due to its low cost inspection cannot help but pay for itself, for even a slight bettering in workmanship will add to the life and strength of the structure. Serious errors are not found on every job, but inspection should be looked upon as insurance against these errors, and insurance which pays its own premiums is very much to be desired.

No one is foolish enough to say that all steel should be inspected. In the case of small jobs the proportionate cost of inspection is higher, and eventually reaches a point where it is economically impossible. Whether or not inspection should be made can be determined by the engineer, who knows all the conditions affecting the structure, such as use to which it will be put, excess of strength, possibility of loads heavier than those used in designing, probable length of life before being torn down, etc. Another factor which should influence it is the reputation which the workers in the shop and field have for careful workmanship, but usually it is not known who will be awarded the steel when the question of inspection is settled, and the engineer is not in a position, as the inspector is, to know the worker's reputation. With all of the conditions balanced against the cost of inspection a decision can be made as to the necessity of inspection. In general it will be found that practically all jobs totalling over 200 tons should be inspected, and certain classes of work, such as those including trusses, if the total is even less.

When an inspection company is to be retained to inspect the steel

the question of who is to pay for it is one which is sometimes given unnecessary importance. If the job is to be let to a general contractor who sublets the steel, the usual method is to specify an allowance to be made by all general contract bidders to cover the cost of inspection, with the condition that the inspection company must be satisfactory to the engineer, if not specified outright. All bids are then made on the same basis, and the control of the inspection remains with the engineer, although the general contractor pays for it. Copies of reports are sent to the engineer, the contractor, and, if desired, the city building department and others interested. If the steel contract is let direct to a fabricator the cost of inspection should be borne by the engineer if possible, and the custom of having the fabricator pay for it should be frowned upon for obvious reasons. In case the cost of the inspection must be included in the steel contract the engineer should appoint the inspector, and this procedure has been requested by the New York Structural Steel Board of Trade and approved by the Structural Engineers' Society of New York.

The fabrication of structural steel by the substitution of welding for riveting is new, but will undoubtedly increase. On account of its newness and the resulting lack of standard practice, welding should be closely supervised to make sure that the specification is being followed, and that good welding is being done. When it is remembered that the cleanness of the surfaces to be welded affects the strength of the weld considerably the necessity of progressive inspection is realized. It should also be borne in mind that whereas most poorly driven rivets can be detected by tapping there is no known method for detecting a weak weld short of destruction, and good work must again be insured by supervision. Experimental work is being carefully done, but welding will shortly be forced to compete in cost with riveting, which means that the factor of high production at low cost will be present with all its attendant evils.

All the statements regarding the value and necessity of inspection which appear in this article are based upon the supposition that the work will be done by an honest, conscientious, and experienced inspector, who will assure himself that the material is in accordance with the requirements, for if inspection is worth doing at all it is worth doing well. Unfortunately not all inspectors are honest, conscientious, and experienced, and the majority sometimes suffer because of the faults of a few. It is easy enough, however, to make sure that it will be done right, whether the inspector is employed directly by the engineer or an inspection company retained, and the matter is too important to be left to chance. Inspection should be awarded by reputation and not by price.



Some fabricators are averse to inspection, principally because they are familiar with cheap inspection. Most reputable manufacturers and fabricators welcome an experienced inspector at their plant, however, for he is of real assistance in helping them maintain a high standard of workmanship, and protects them against losses due to mistakes.

Inspection has its place in industry, but it is sometimes misunderstood. It is hoped that this article has given information which will aid in forming a clear idea of inspection. If it is a function of structural engineering to take all necessary precautions to insure that steel shall be furnished and erected in accordance with the requirements under which it is bought, then the inspection of structural steel is necessary.

## OF GENERAL INTEREST

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### HOOSAC TUNNEL ENLARGEMENT\*

An outstanding engineering accomplishment was completed December 1, 1926, when the Hoosac Tunnel, enlarged to permit the passage of the largest cars used by the railroads of the country, was opened for full operation on both east and west bound tracks. This increase in the size of the  $4\frac{3}{4}$  mile bore, which for half a century has provided the shortest route by rail between the Hudson River and the sea, is considered as remarkable in its way as the original project.

The result will be a saving of 24 to 36 hours in some shipments. On account of the increase in size of freight cars in recent years, many were detoured over roundabout routes. The tunnel is now large enough to permit the operation of the largest cars in trains moving in opposite directions on both tracks at the same time.

With the so-called "Little Tunnel" west of North Adams also enlarged, with bridge clearances being increased over the entire route, bridge-strengthening under way to permit the operation of the giant Santa Fé locomotives and their hundred-car trains all the way east, rock-ballasting operations well begun, and automatic train control installed for more than half the distance, the Fitchburg-Berkshire division will be one of

the best-equipped railroad lines in the country. Over its 187 miles between Mechanicville, N. Y., and Boston is handled annually 45 per cent of the freight business of the entire system.

The work was in progress during the peak season of the year in freight movements. An average of 1,700 freight cars a day, and all passenger trains, including the "Minute Man" between Boston and Chicago, had to be protected. A single blast carried too far might have blocked the tunnel and undone the work of years.

To run the trains, a current of 11,000 volts was kept alive to provide power for the electric locomotives which for 15 years have hauled Hoosac Tunnel trains, eliminating the former smoke nuisance.

As the miners came out of the West Portal blinking in the bright dawn of Thanksgiving morning, they were reminded of the fact that it was on Thanksgiving Day, 1873, that the original tunnel builders brought the east and west headings together, with an error of only nine-sixteenths of an inch.

With the maximum clearance of 16 feet 3 inches between top of rail and battery wire the enlarged tunnel will be 5 inches higher than the highest car on record — 15 feet 10 inches — and will be able to accommodate cars with a maximum width at eaves of 10 feet 6

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inches at a height of 14 feet above the rail.

The work of enlarging the tunnel was handled by Boston & Maine men. The maintenance of way organization, under W. J. Backes, conducted the operations, which were in immediate charge of W. J. Shanks as construction superintendent. The plans were drawn by Division Engineer J. P. Canty and Mr. Shanks, with the engineering details worked out by G. A. Haskins of the maintenance of way forces, who was engineer in charge. As chief construction engineer F. C. Shepherd drew up the estimates which decided the Boston & Maine management to undertake the job, and trains were operated through the tunnel under the direction of Division Superintendent J. A. Ahern, together with Trainmasters G. W. Blake and R. O'Brien.

The following interesting account of how the work was done is furnished by Division Engineer J. P. Canty:

In planning for this work there were no precedents available to guide as to practical, economical and satisfactory handling under the conditions existing within a period which would be considered as reasonable. Therefore — as at the time when this same tunnel was originally bored — methods were developed to accomplish what was desired.

The possibility of hauling the tonnage anticipated in both directions on one track was given very thorough consideration by the transportation department, and it was decided that by a rearranged spacing of some trains which would permit them to arrive at each Portal of the tunnel at specified times, the traffic could be handled over this piece of single track without any increase in electric motive power.

With the decision that exclusive possession of one track by the maintenance of way department would be arranged for during the period necessary for doing the work required, and with the understanding that active work should be carried along continuously during 24 hours daily,

much consideration was then given to equipment needed to efficiently carry out the project. Such maintenance of way department equipment as could be spared was assembled and some additional apparatus was purchased.

The first consideration given to each part of the proposition was along the line of safety to traffic and employees, and then the efficiency of the methods was analyzed. Quite a few schemes were gone into and discarded as not filling the requirements.

In choosing the equipment to be purchased it was decided to obtain such as could be used afterwards for regular maintenance of way department requirements, as far as possible.

The overhead trolley wires were raised from a minimum height of 15 feet 11 inches to 16 feet 3 inches. To accomplish this much stone was blasted out of the rock roof in places over the insulators and wires.

Through the rock sections where inadequate clearances existed for eaves of high cars — that is, those with a height of 14 feet 0 inches and 10 feet 6 inches wide — the solid ledge was drilled with pneumatic tools and blasted out with dynamite.

In the aggregate this amounted to quite a proposition, as work was done on one track at a time — with electric power shut off — without removing the wires or hangers, and without shutting off electric current on the other track.

Where the tunnel is brick lined and where clearances were inadequate through such sections — particularly through the most westerly brick-lined sections, that is, over a length of about 3,500 feet just east of the West Portal and also over a stretch about 500 feet westerly of West Portal, outside tunnel — both tracks were lowered.

The major excavation over a length of about 4,000 feet near West Portal was at its greatest depth about 2 feet and 9 inches. This stretch provided for removing ballast and floor of tunnel under the ties so as to permit installing new crushed stone ballast to a depth of 8 inches under bottom of ties when track was lowered to its new grade. About two-thirds of the



excavated material in this section under the track was solid stone, some of it being a very hard flint which was almost impossible to drill and very difficult to break up.

To add to the difficulties there was a considerable flow of water (about 600 gallons per minute) coming out of the West end of the tunnel in a stone box culvert. It was necessary to remove this old stone box, which was located in center between tracks, and lower the grade of

nished by compressors, — in duplicate, — one electrically and the other gasoline operated, located at West Portal — the air being supplied to the equipment through a 3-inch pipe, laid inside of tunnel full length of the major operations, with outlets every 100 feet.

For the overhead rock excavation an ordinary flat car was provided with a raised platform upon which the miners operated the pneumatic stone drills, air for the drills being furnished by a port-



ORIGINAL SURVEYORS OF THE HOOSAC TUNNEL (ABOUT 1851)

the bottom of same in places through solid rock to permit lowering the tracks, the stone box culvert being replaced with reinforced concrete pipe.

The matter of handling the excavated material under the track and disposing of it without interfering with trains was probably the most difficult problem to solve. The limited space both inside and outside of the tunnel necessitated equipment in many ways similar to that used in mines. Inside of tunnel all equipment, except that used for hauling spoil cars, was operated by compressed air, fur-

able gasoline motor-driven compressor. This unit, of platform car and compressor, started at Central Shaft and worked down grade to each Portal. Stone was removed from the roof and walls by this outfit in comparatively small pieces and deposited in a windrow between tracks, to be removed later by a regular work train.

At various places through tunnel, where tracks were lowered slightly to obtain the required clearance through the brick-lined sections, they were simply dropped by digging out by hand between

and under the ties, the refuse ballast being deposited between the tracks and later loaded up by hand and carried out of tunnel through the East Portal by our regular work train. The total length of single track dropped up to a maximum of 5 inches by this process was about 4,950 feet.

At the West end of tunnel, where both tracks were lowered about 18 inches, a power shovel backed into the tunnel on the original standard gauge track, the latter being removed in 16½ foot sections as the shovel backed into the bore. After material to be excavated was shattered by pneumatic "paving breakers" or by dynamite, as required, it was loaded up on "scale boxes" with a capacity of about 2 cubic yards, which were placed on small flat cars about 5 feet wide and 8 feet long on a 3-foot gauge track, constructed behind the shovel as it advanced into the hole. A portable turnout on this narrow-gauge track was kept fairly close to the shovel as it backed into the opening, and a heavy duty gasoline narrow-gauge motor car hauled the cars out to West Portal. Here the loaded scale boxes were hoisted on an aerial carriage—operated by a steam hoisting engine—up to a cableway extending over the Portal to a comparatively flat area over the tunnel just east of the Portal, where they were dumped, making two noticeable ridges about 35 feet high on top of tunnel.

The stretch covered by our major operation was kept well lighted with incandescent electric lamps spaced 100 feet apart. Carbic flare lights were used on remainder of work.

The organization that did this work was rather an interesting and efficient force, wholly collected from vicinity of North Adams. As the length of time in which the work would be performed depended primarily on the speed of the excavators of the tunnel floor, all other operations were regulated so as not to interfere with that part of the work. Therefore, the excavating outfit and men were continuously in service 24 hours each day, from August 11—when the work actively commenced—until No-

vember 25—on which date the floor excavating work was completed.

It may be of interest to enumerate the various kinds of workers engaged on the project. To illustrate, during the week ending November 25 the following were employed: 2 supervisors, 1 timekeeper, 4 civil engineers, 1 electrical foreman, 5 electrical workers, 8 foremen, 7 assistant foremen, 3 excavating outfit operators, 2 hoisting engine operators, 1 blacksmith, 1 carpenter, 4 pipers, 4 masons, 1 ventilating plant operator, 1 ventilating plant operator's helper, 2 cooks, 36 miners, 95 laborers; total men, 178.

In order to keep these men effectively employed and the various lines of work co-ordinated so that there would be no interference one crew with another, and that all crews also should give precedence to the floor excavating corps, and that all lines of work required for opening up the tracks again should be finished no later than the pace-making part of the project—that is, the floor excavating—it was necessary that all concerned in directing this undertaking should be on the alert continually.

Quite a proportion of the force employed (about 50 per cent) were hired especially for this work. One might expect that pay time would be the most interesting part of the week to them. However, this was not in evidence.

In my railroad experience I have not previously seen, on any job, so much interest exhibited in what we desired to accomplish, or such earnestness in trying to do one's part. Furthermore, the accomplishment per man under such exacting conditions as surrounded this job was such as to incite very favorable comment.

I venture to say that the somewhat unusual character of the work raised it out of the drudgery class and kept all concerned much interested in its progress. The project was carried out under considerable tension without anything more serious than a comparatively few minor personal injuries.

With the exception of such freight train delays as may be attributed to running over a single track (there were

practically no passenger train delays) the work was carried along with no interference with traffic. When one considers that there were between 40 and 44 trains passing through the tunnel daily—and some freight trains carried as many as 100 cars, taking upwards of 20 minutes to pass through—this record reflects great credit on the train dispatchers and particularly the signal tower operators at both East Portal and West Portal.

The joint handling by the transportation department with the maintenance of way department was excellent.

The promptness with which needed repairs on the equipment were taken care of by the electric locomotive repair shop at North Adams, and the preferred attention given by the purchasing department to the requisitions for material required, also deserve commendation.

## PROCEEDINGS OF THE SOCIETY

### APPLICATIONS FOR MEMBERSHIP

[September 20, 1928]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

#### *For Admission*

FAIRBANKS, H. KENNETH, Augusta, Me. (Age 31, b. Hyde Park, Vt.) Experience: 1916, three months as rodman on river

survey; 1919, four months as assistant engineer, hydro-electric construction; 1920, four months as transitman, Swift River surveys; 1921–23, assistant engineer with N. S. Hill, Jr., on valuations, rate cases, design and supervision construction; 1923, March to July, designer with Dwight P. Robinson; July, 1923, to November, same year, designer with Turner Construction Company; November, 1923, to April, 1925, designing engineer with Ambursen Construction Company; April, 1925, to date, designing engineer with New England Public Service Company, Augusta, Me., and since April, 1926, as chief of design. Refers to *Erwin Harsch, K. R. Kennison, E. G. Lee, J. D. Mitsch, H. M. Turner.*

HICKEY, WILLIAM, Brookline, Mass. (Age 21, b. Brookline, Mass.) At present am attending Franklin Institute, taking a course in surveying. For the past three and a half years have been employed by Mr. Henry F. Bryant as rodman, transitman and concrete inspection. Refers to *H. F. Bryant, W. A. Bryant, H. C. Cook.*

PACKARD, FRANK E., Jr., Greenwood, Mass. (Age 31, b. E. Somerville, Mass.) Attended Norwich University in 1917; U. S. Army, 1918–19; Norwich University, 1919; 1919–20, draftsman with Massachusetts Waterways and Public Lands Commission; 1920, construction work, Smith-Powers Company; 1921–25, in



other business than engineering; 1925 to date, instrument man, inspector and chief of party with Erastus Worthington. Graduate of Northeastern University, Evening Polytechnic School, 1928. Refers to *W. J. Alcott, Jr., C. O. Baird, Jr., L. M. Hersum, E. N. Hutchins, Erastus Worthington.*

PROUD, ERNEST L., Beverly, Mass. (Age 23, b. Beverly, Mass.) Employed one year by the New England Structural Company of Everett, as structural detailer; three years with Boston & Maine Railroad as chainman, rodman and draftsman; from May 1, 1927, to date, as transitman and draftsman for South Essex Sewerage District, Salem, Mass. Refers to *E. S. Averell, W. H. Fowler, C. L. Nyman, J. J. Vertic.*

MOORE, DANIEL MARTIN, Taunton, Mass. (Age 39, b. Taunton, Mass.) Studied civil engineering at Massachusetts Institute of Technology 1909-11, 1913-15; 1912, three to four months with Massachusetts Highway, also private house construction; 1913, nine months with the Directors of the Port of Boston; 1915-16, with Public Service Commission, on track design, under D. L. Turner; 1916-17, B., R. & P. Ry., Rochester, N. Y., as draftsman; 1917-23, in engineering department, Boston & Albany Railroad, as chief of party on construction; 1923-25, leading draftsman with P. & L. E. R.R.; 1925-26, private engineering and contracting; 1927, valuation department, New York, New Haven & Hartford Railroad; 1928, private engineering and construction. Refers to *J. W. Howard, M. H. Mellish, C. A. Moore, L. G. Morphy, H. L. Ripley.*

*For Transfer from Grade of Junior*

CARCHIA, MICHAEL A., W. Roxbury, Mass. (Age 27, b. Newark, N. J.) Attended Tufts College, 1920-23, and Northeastern University, 1923-24. Since graduation have been State Highway superintendent and engineer for L. C. Carchia Company to date. Refers to *Robinson Abbott, W. J. Alcott, Jr., H. B. Alvord, P. E. Bodemer, A. O. Bradshaw.*

FOX, VERNALD WADSWORTH, Point Independence, Mass. (town of Wareham).

(Age 28, b. Alton, Me.) After graduation from the North Attleborough High School in 1920 he spent one year at Northeastern University, completing a school year and a summer course in electrical-mechanical engineering. From July, 1921, to Sept. 20, 1922, again worked in order to resume his studies. Through the help of Ex-Mayor Sweet's influence he was transferred from Northeastern to Tufts Engineering School, in the same course. At the end of the mid-year was obliged to leave on account of health, but after recovering to some degree was employed by the Boston & Maine Railroad as draftsman in department of bridges and buildings; was here from April to Oct. 16, 1923, and then took a position with Mr. O. H. Tripp, Rockland, Me., as draftsman and general assistant, until Mr. Tripp became ill and was obliged to let him go in January, 1924; then entered the employ of Stone & Webster, Inc., as draftsman until June 8, 1925, when he was employed by the Massachusetts Highway Department, and at present has a transitman's rating and is assistant to a resident engineer on road construction. Refers to *Robinson Abbott, W. J. Alcott, Jr., J. B. Babcock, E. R. McCarthy, E. D. Mortenson.*

MATHER, ERNEST, Milton, Mass. (Age 25, b. Johnsonburg, Pa.) Graduate of Northeastern University. From 1926 to date, engineering assistant with Metropolitan District Commission. Refers to *H. B. Alvord, D. A. Ambrose, W. H. Cronin, E. P. McSweeney, W. E. Nightingale.*

SIMONDS, LERMOND FALES, Auburn-dale, Mass. (Age 25, b. Auburn-dale, Mass.) Had two years in Massachusetts Institute of Technology. Experience in field office of H. P. Converse & Co., on Bronx Terminal market job; engineer with H. P. Cummings Construction Company; assistant civil engineer on steel pipe lines of Weston Aqueduct supply mains; estimator and finally in charge of engineering department, Standard Plate Glass Company; and at present local manager, Construction Survey Company, New Haven, Conn. Refers to *Clifford Foss, E. J. McDonald, A. Q. Robinson.*



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## DEATHS

- HEZEKIAH BISSELL.....June 24, 1928  
 THOMAS S. BURR.....July 25, 1928  
 HERBERT N. CHENEY.....Sept. 12, 1928  
 CHARLES H. GANNETT.....Aug. 20, 1928  
 FRANKLIN M. MINER.....Sept. 15, 1928  
 JOHN R. RABLIN.....Sept. 17, 1928



## BOSTON SOCIETY OF CIVIL ENGINEERS

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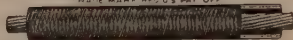
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